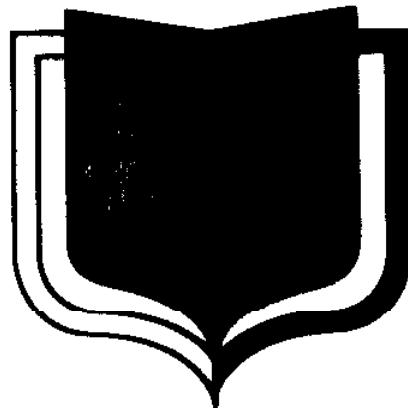
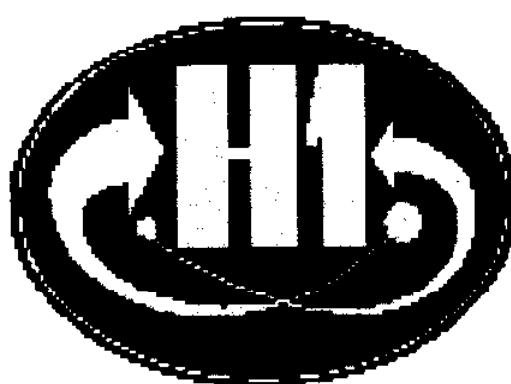


Diffraction Dissociation in Photoproduction at HERA

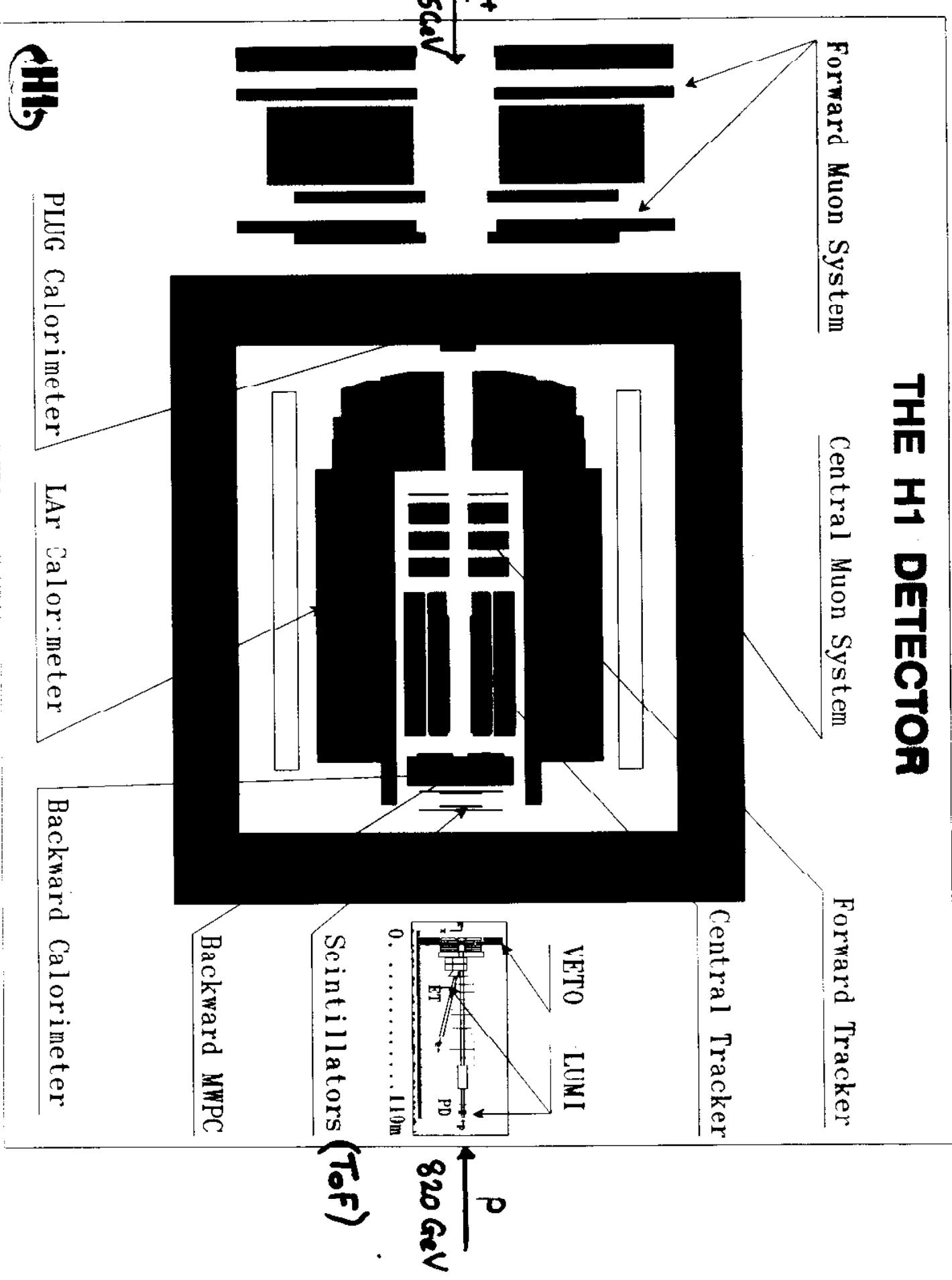
DESY 97-009 hep-ex/9702003



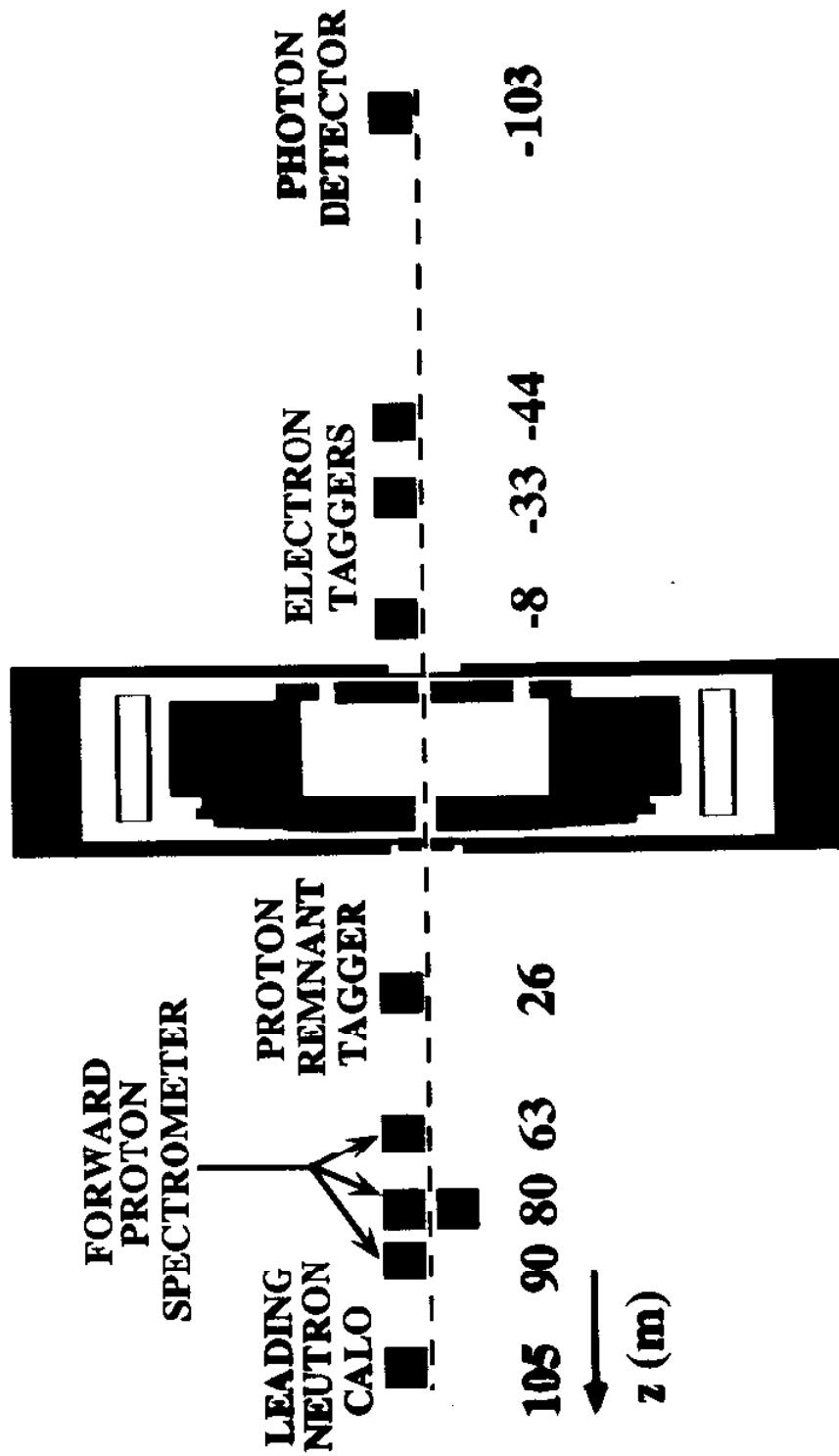
Paul Newman
Birmingham University
For the H1 Collaboration.

- Introduction to the H1 Detector.
- Soft Photoproduction.
- Hadron Level Cross Section Definitions.
- Experimental Procedure.
- Measurements of Dissociation Cross Sections.
- Regge Analysis of the Cross Sections.

THE H1 DETECTOR



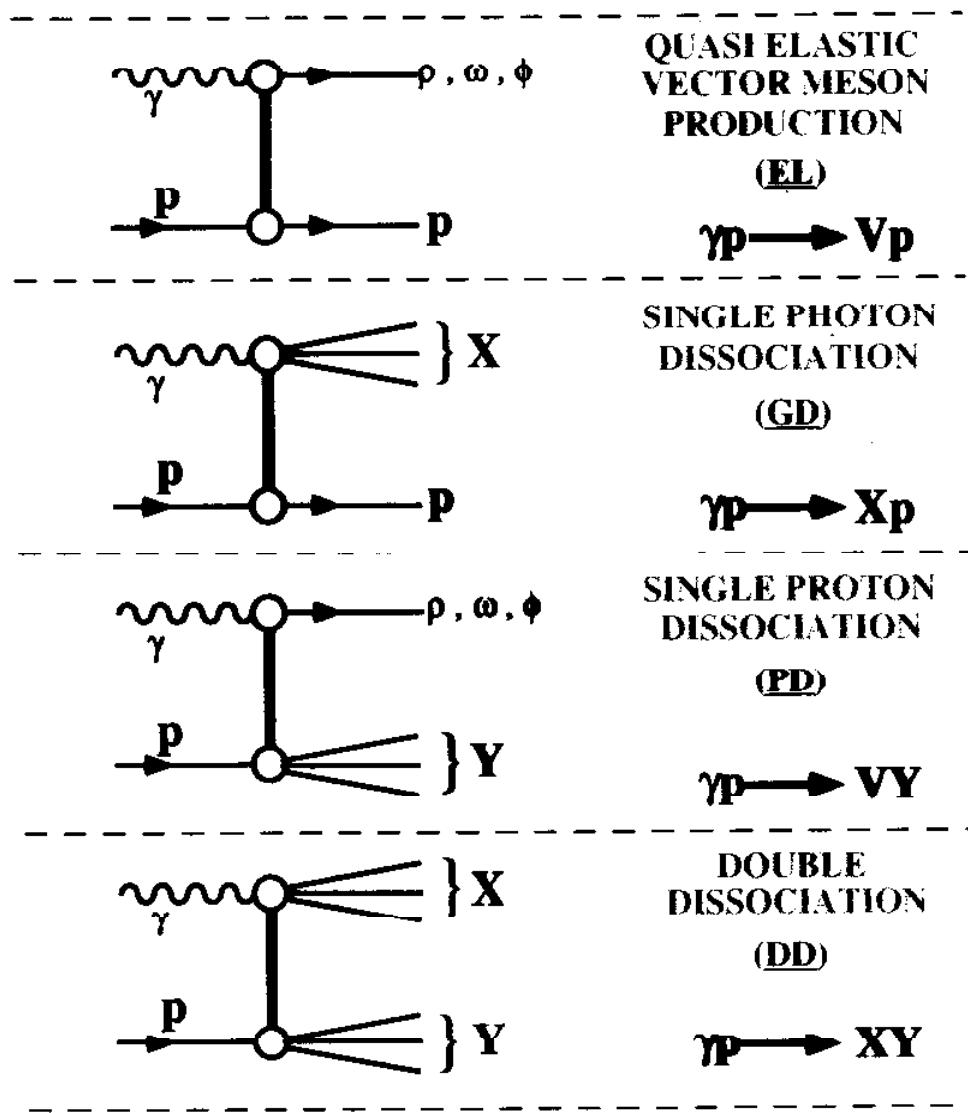
BEAM-LINE INSTRUMENTATION



Say bit in middle is H1
Just start talk about PRT

COLOUR-SINGLET EXCHANGE PROCESSES IN PHOTOPRODUCTION

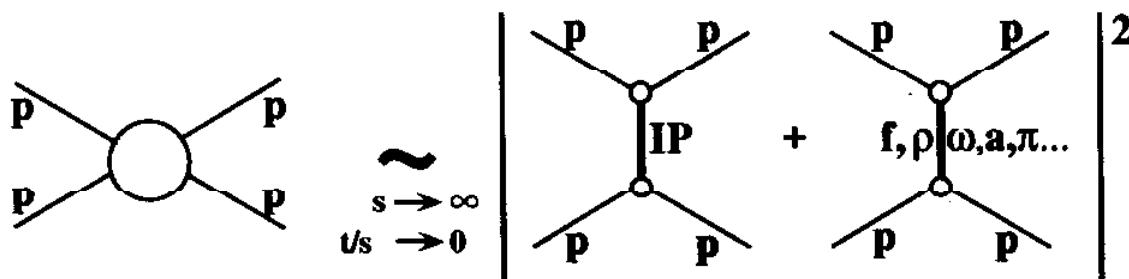
Soft photoproduction is very similar to soft hadron-hadron interactions (VDM).



With the H1 Detector, all four processes can be measured both in photoproduction and at high Q^2 .

Diffractive and Non-Diffractive Exchanges

- We define Diffraction $\equiv \text{IP exchange}.$
- “Diffractive” and “non-diffractive” colour-singlet exchanges both contribute to the measured cross section. *(Point out that this was the same for all previous experiments)*



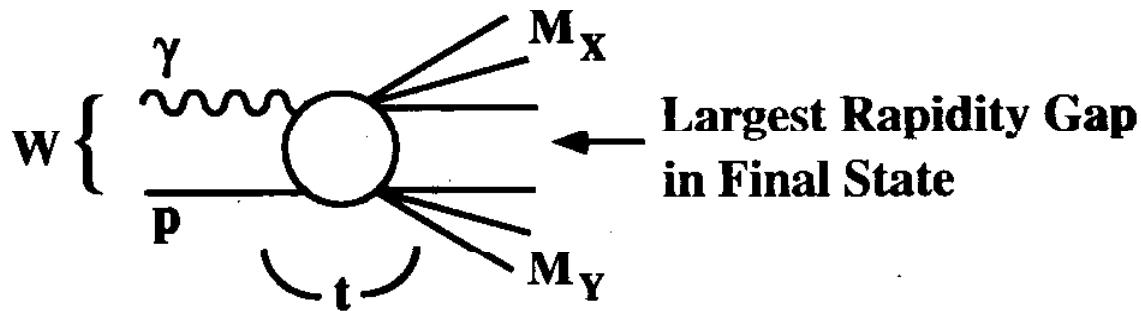
- Leading and sub-leading exchange contributions are indistinguishable on an event by event basis.
- There can even be interference (e.g. IP/f).
- The sub-leading contributions are generally much more complicated than the pomeron exchange contribution.

Make sure you obtain the kinematics here as well!

Definition of the Measured Cross Section

To ensure model independence, the measured cross section is defined in terms of physical observables.

i.e: At the hadron level.



- All final state particles are first ordered in rapidity.
- X and Y are, by definition, separated by the largest gap in this rapidity distribution.
- Where M_X and M_Y are small, a large rapidity gap is forced kinematically, giving a clear separation between X and Y .

The cross section $\frac{d\sigma(\gamma p \rightarrow XY)}{dM_X^2}$ is measured at fixed values of W , integrated over ranges in M_Y and t .

The “diffractive” contribution is extracted from this measured cross section with varying model assumptions.

Data trigger samples

Data Samples

<i>TRIGGER</i>	<i>NOMINAL VERTEX</i> ($z_0 \simeq +5$ cm)	<i>SHIFTED VERTEX</i> ($z_0 \simeq +70$ cm)
eTag \times ToF	$24.7 \pm 0.4 \text{ nb}^{-1}$	$23.8 \pm 1.3 \text{ nb}^{-1}$
eTag \times vertex	$22.8 \pm 0.4 \text{ nb}^{-1}$	

- The ToF trigger gives high efficiency throughout the M_X , M_Y range.
- The vertex trigger provides cross checks at large M_X .
- Two minimally biased photoproduction samples are obtained with $\langle W \rangle = 187 \text{ GeV}$ and $\langle W \rangle = 231 \text{ GeV}$.
- Rapidity gap selections are applied to obtain samples with small M_X and M_Y .

Monte Carlo Models

- Averages of PHOJET and PYTHIA Monte Carlo models are used to correct the data.
- Both are based on the VDM and Regge theory.
- Both contain all four colour-singlet exchange and non-colourless exchange processes.
- The M_X distributions and ratios of sub-processes in both Monte Carlos are weighted to best match the results of the measurement.

Reconstruction of Invariant Masses

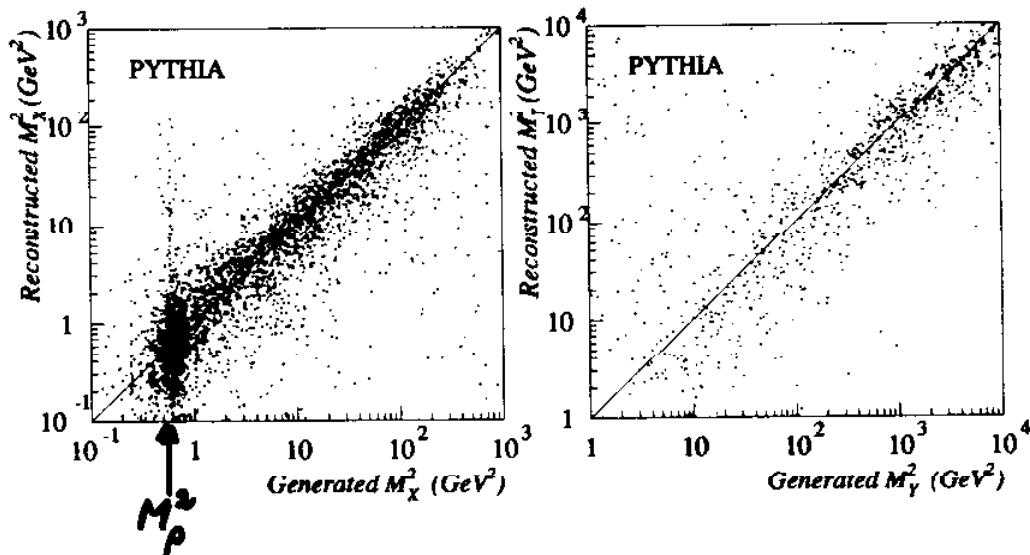
M_X and M_Y are reconstructed using an energy flow algorithm that takes account of tracking and calorimeter information without double counting.

M_X is reconstructed in a manner that is insensitive to losses in the backward direction where $E \simeq -p_z$.

$$M_X^2 = 2\gamma.X + Q^2 + t \sim 2E_\gamma(E + p_z)_X$$

Where there is significant activity from Y in the main detector, M_Y is reconstructed in a similar manner, but insensitive to losses in the forward direction where $E \simeq p_z$.

$$M_Y^2 = 2p.Y - m_p^2 + t \simeq 2E_p(E - p_z)_Y$$



Show next fail = 1
each time after
describing each
set of cuts.

Selection of Intervals in M_Y

The cross section $\frac{d\sigma}{dM_X^2}$ is measured in two ranges of M_Y and t :

1) $M_Y < 1.6 \text{ GeV}, |t| < 1 \text{ GeV}^2$ ($\sim \text{GD, EL}$)

- $\eta_{\max} < 3.2$.
- No Proton Remnant Tagger hits.
- ≤ 1 Forward Muon pre-toroid pairs.

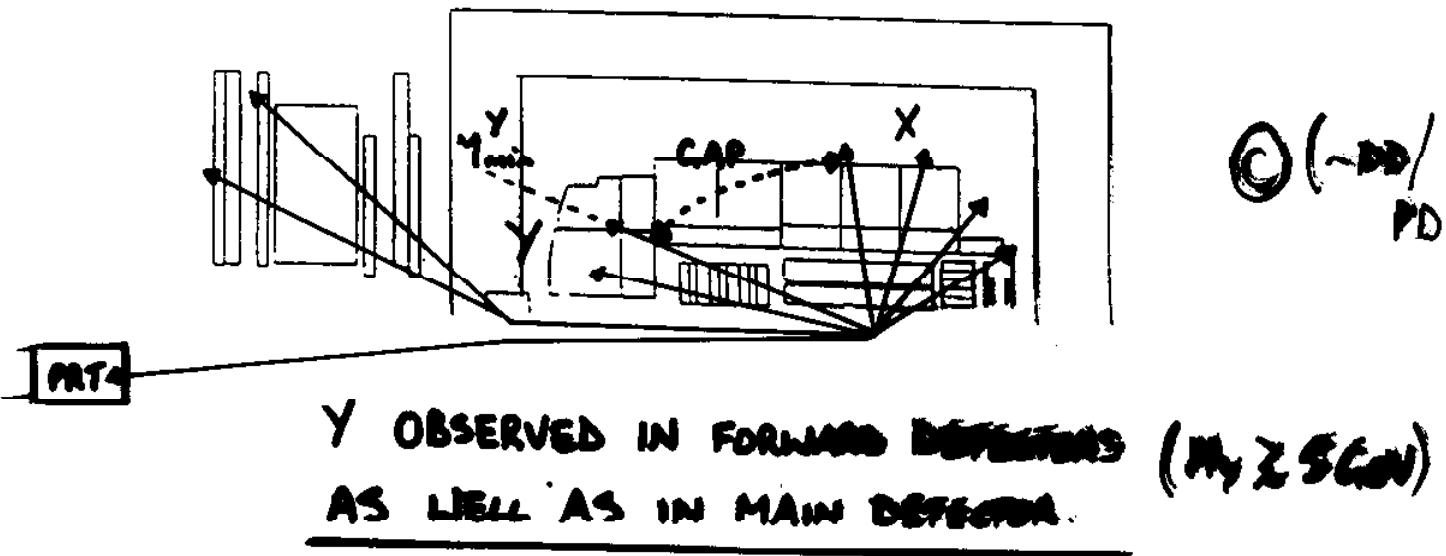
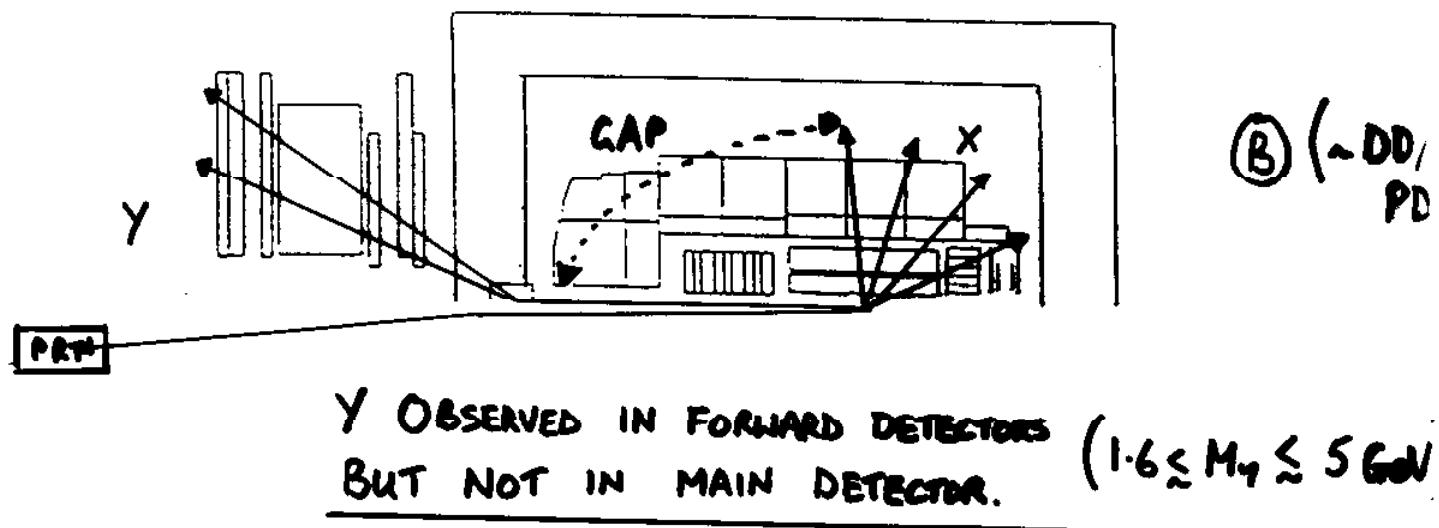
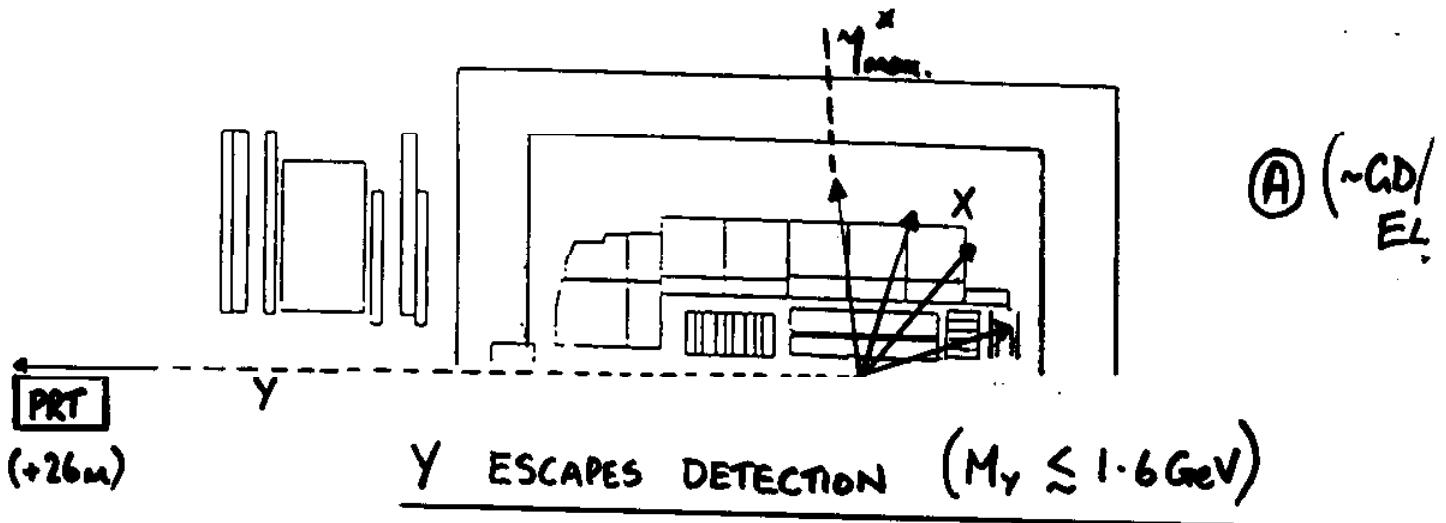
With these cuts, there is a pseudo-rapidity gap spanning at least $3.2 \lesssim \eta \lesssim 7.0$.

2) $1.6 < M_Y < 15.0 \text{ GeV}$, all $|t|$ ($\sim \text{DD, PD}$)

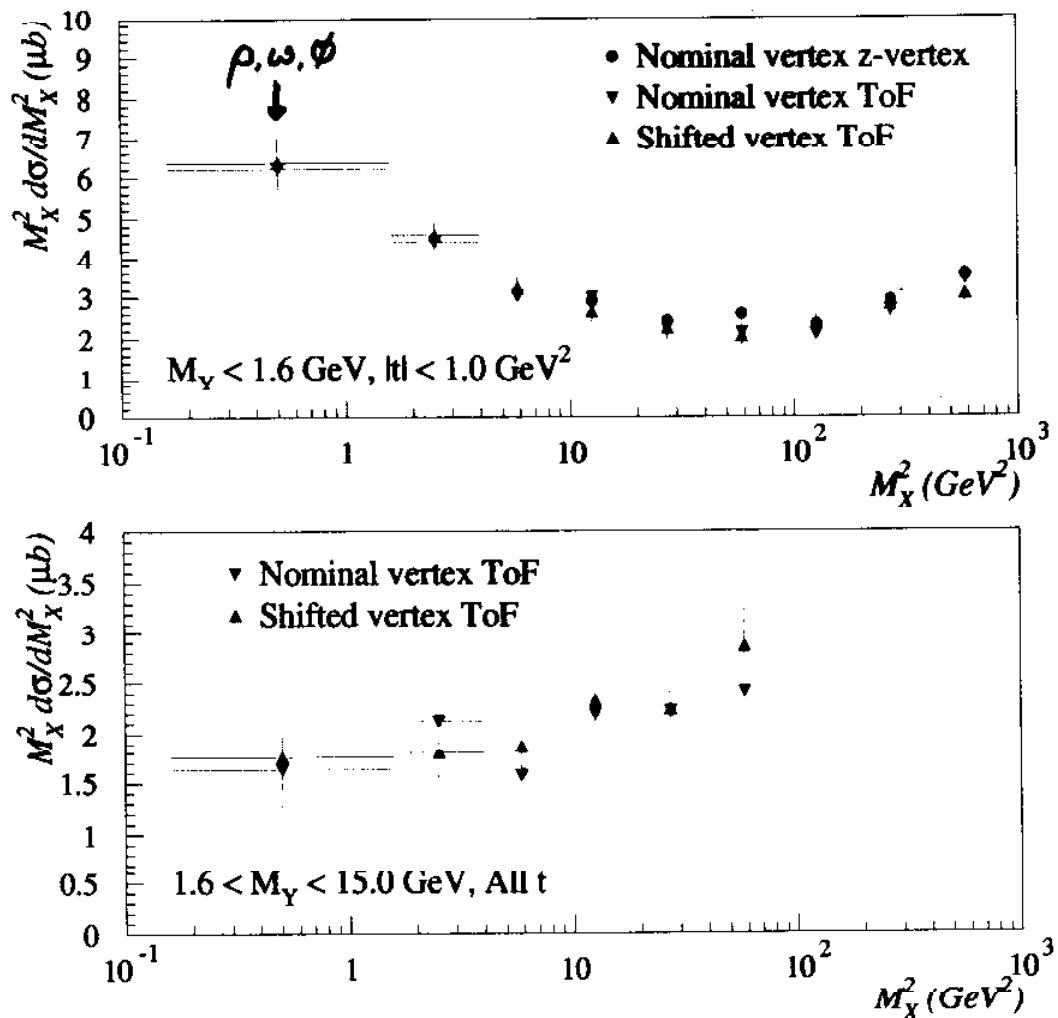
- A gap of > 2 pseudo-rapidity units in the main detector.
- Activity in either the PRT or the FMD.
- If the largest gap in the main detector is not at forward limit of acceptance.

$$M_Y^{\text{rec}} = 2E_p(E - p_z)_Y < 15.0 \text{ GeV}.$$

~~SLIGHTLY DIFFERENT TYPES OF TOPOLOGY ARE CONSIDERED~~

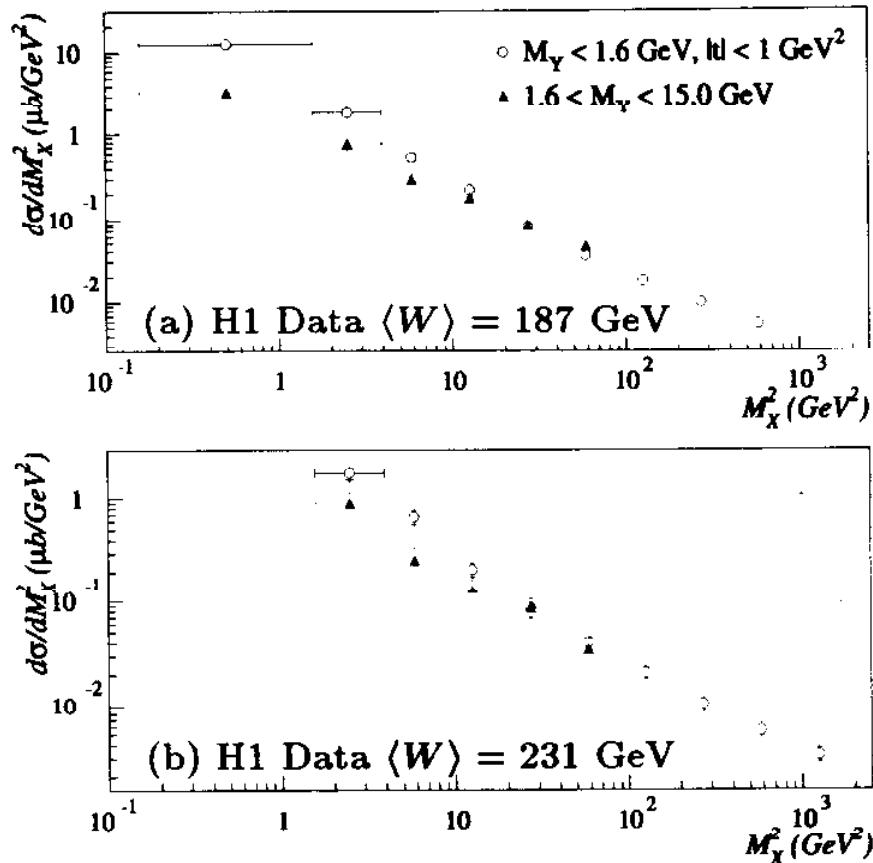


Comparison of Measurements of $M_x^2 \frac{d\sigma}{dM_x^2}$ Using Different Data Samples, $164 < W < 212$ GeV.



The two ToF samples are combined to produce the final cross sections.

Final Cross Sections $\frac{d\sigma}{dM_X^2}(\gamma p \rightarrow XY)$



The measured cross sections closely resemble hadron-hadron data (except in overall normalisation):

- In both ranges of M_Y , there is an approximate $\frac{d\sigma}{dM_X^2} \sim \frac{1}{M_X^2}$ dependence (but see later).
- When both M_X and M_Y are small (EL region), there is a considerable enhancement compared to this.
- At large M_Y , the M_X dependence is noticeably shallower than that at small M_Y . Say $0.84 \pm 0.06 \pm 0.18$

A Triple Regge Model for the data with $M_Y < 1.6 \text{ GeV}$

The low M_Y sample is likely to be heavily dominated by the process, $\gamma p \rightarrow Xp$.

A constant correction factor is applied:

$$M_Y < 1.6 \text{ GeV} \xrightarrow{\times 0.90 \pm 0.06} Y \text{ is a bare proton.}$$

[ASSUMES ONLY STATES WITH $I = \frac{1}{2}, I_3 = +\frac{1}{2}$ CONTRIBUTE]

$$\text{e.g. } N^{\frac{1}{2}+}$$

In order to investigate both the M_X^2 and the W dependence of the cross section, a simultaneous fit is performed to H1 and fixed target data.

E612 (1985) measured $\left. \frac{d\sigma(\gamma p \rightarrow Xp)}{dM_X^2 dt} \right|_{t=-0.05 \text{ GeV}^2}$
at $W = 12.9 \text{ GeV}$ and $W = 15.3 \text{ GeV}$.

Only data with $M_X^2 > 4 \text{ GeV}^2$ are considered.

Don't forget to explain all the terms ...

Triple Regge Formalism

For $W^2 \rightarrow \infty$, $t/W^2 \rightarrow 0$, the W dependence of a process $\gamma p \rightarrow X p$ may be expressed in terms of a sum of t -channel Regge exchanges.

$$\left| \sum_i \frac{\gamma}{p} \alpha_i(t) \frac{p}{p} \right|^2 \quad W \text{ dep}$$

Mueller's generalisation of the optical theorem relates the sum of processes $\gamma \alpha_i(t) \rightarrow X$ at fixed M_X to the forward amplitude for $\gamma \alpha_i(t) \rightarrow \gamma \alpha_i(t)$.

M_X dep

$$\left| \sum_{i,X} \frac{\gamma}{p} \alpha_i(t) \frac{p}{p} \right|^2 = \sum_{i,j,X} \left| \begin{array}{c} \gamma \\ \alpha_i(t) \\ \hline \text{---} \\ \alpha_j(t) \\ \hline p & p \end{array} \right|^2 = \sum_{i,j,k} \left| \begin{array}{c} \gamma \\ \alpha_i(t) & \alpha_j(t) \\ \hline \text{---} \\ \alpha_k(0) & \alpha_j(t) \\ \hline p & p & p \end{array} \right|^2$$

Then for $W^2 \gg M_X^2 \gg m_p^2, t$, both the W^2 and M_X^2 dependence is given by:

Say $s_0 = 1 \text{ GeV}^2$

$$\frac{d\sigma}{dt dM_X^2} = \sum_{i,j,k} \frac{G_{ijk}(t)}{W^4} \left(\frac{W^2}{M_X^2} \right)^{\alpha_i(t) + \alpha_j(t)} \left(\frac{M_X^2}{M_X^2} \right)^{\alpha_k(0)} \cos \frac{\pi}{2} [\alpha_j(t) - \alpha_i(t)]$$

$$G_{ijk}(t) = \frac{1}{16\pi} \beta_{pi}(t) \beta_{pj}(t) \beta_{\gamma k}(0) g_{ijk}(t) \sim G_{ijk}(0) e^{Bt}$$

For the triple diagram, the predicted intercepts are

Pomeron exchange: $\alpha_{\text{IP}}(0) \sim 1.08 + 0.25t$

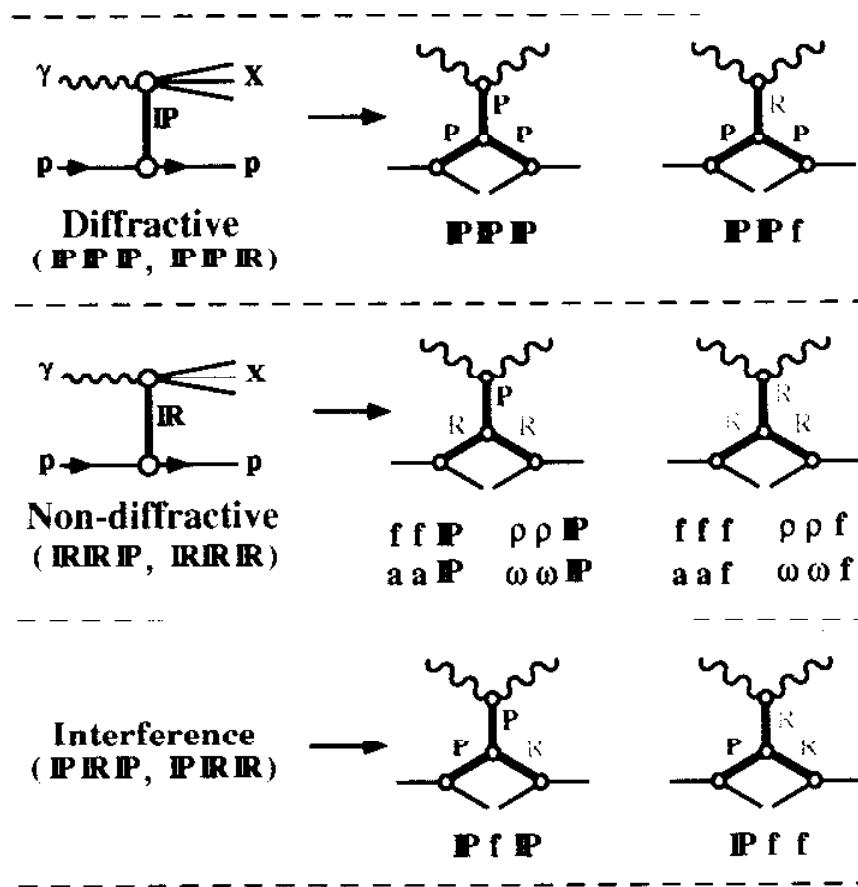
Meson (f, ω, a, ρ) exchange: $\alpha_{\text{IR}}(0) \sim 0.55 + 0.90t$

- The couplings $G_{ijk}(0)$ of each triple diagram term and the pomeron intercept $\alpha_{\text{IP}}(0)$ are fixed by these parameters.
- The remaining parameters required are obtained from other data:
 - $\alpha_{\text{IR}}(0)$ Total hadron-hadron cross section
 - α'_{IP} Singlet channel coupling constant
 - α'_{IR} Singlet channel coupling constant
 - Vertex t dependences for the assumed energy triple diagram terms

Quantity	Assumed Value		
$\alpha_{\text{IR}}(0)$	0.55	± 0.10	
α'_{IP}	0.26	± 0.02	GeV^{-2}
α'_{IR}	0.90	± 0.10	GeV^{-2}
$b_{p\text{IP}}$	2.3	± 0.3	GeV^{-2}
$b_{p\text{IR}}$	1.0	± 1.0	GeV^{-2}
b_{ijk}	0.0	± 1.0	GeV^{-2}

Don't
explain
where
fixed
parameters
come from

and possible different vertex terms:



Say what can mediate charge/isospin exchange.

- C-parity must be conserved at the $i j k$ vertex.
- C- and G- parity must be conserved at the $i j k$ vertex.

Generic term	Appr. W dependence	Appr. M_X dependence	
PPP	W^0	M_X^{-2}	} DIFF.
PRR	W^0	M_X^{-3}	
IRRIP	W^{-2}	M_X^0	} NON-DIFF.
IRRIR	W^{-2}	M_X^{-1}	
$\{\text{IPR}\}\text{IP}$	W^{-1}	M_X^{-1}	} INT. assumption
$\{\text{IPR}\}\text{IR}$	W^{-1}	M_X^{-2}	

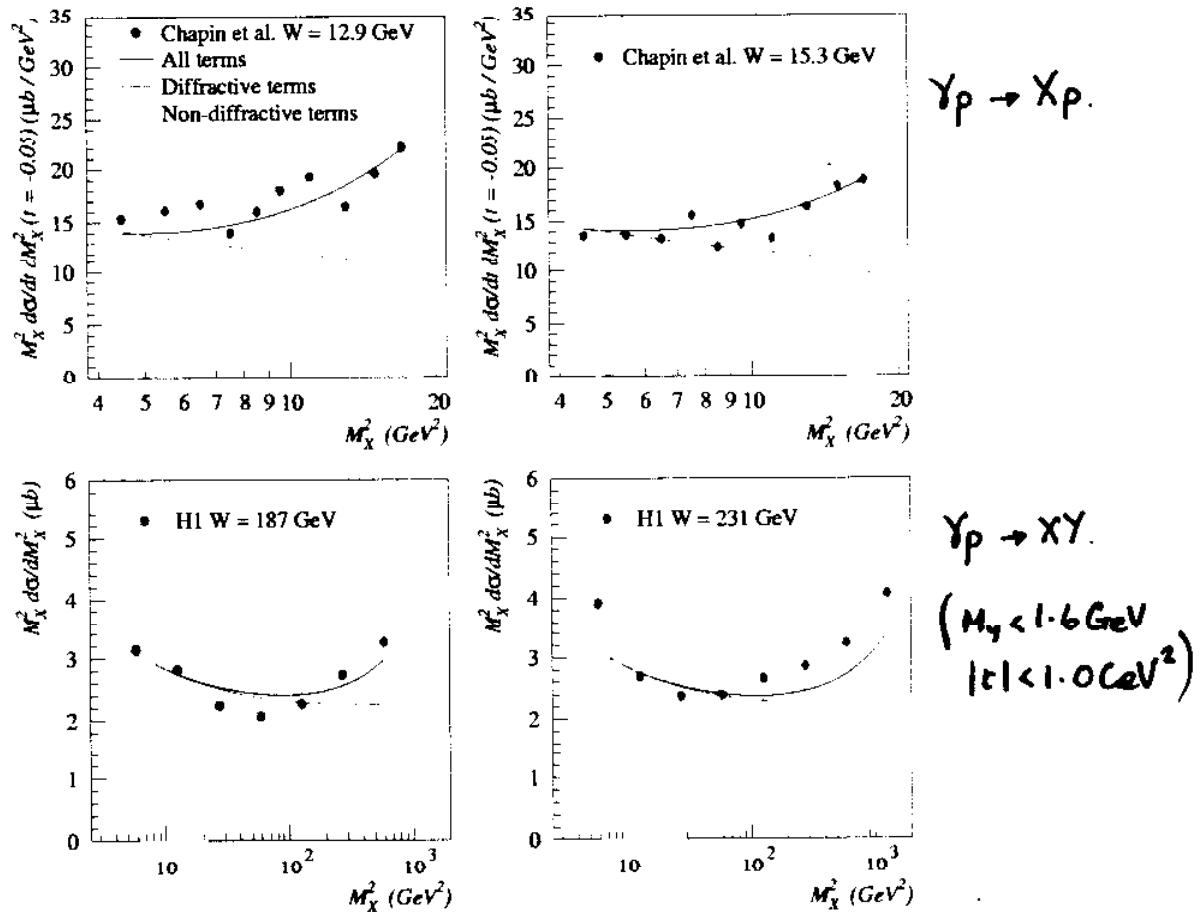
State the assumptions.

Triple Regge Fit

- PPPP, PPIR, RRP, RIRR terms.
- No Interference.
- No isospin-1 exchange.

} ROUGHLY EQUIVALENT
TO $R = \omega$.

$$\chi^2/\text{n.d.f} = 28.8/30.$$



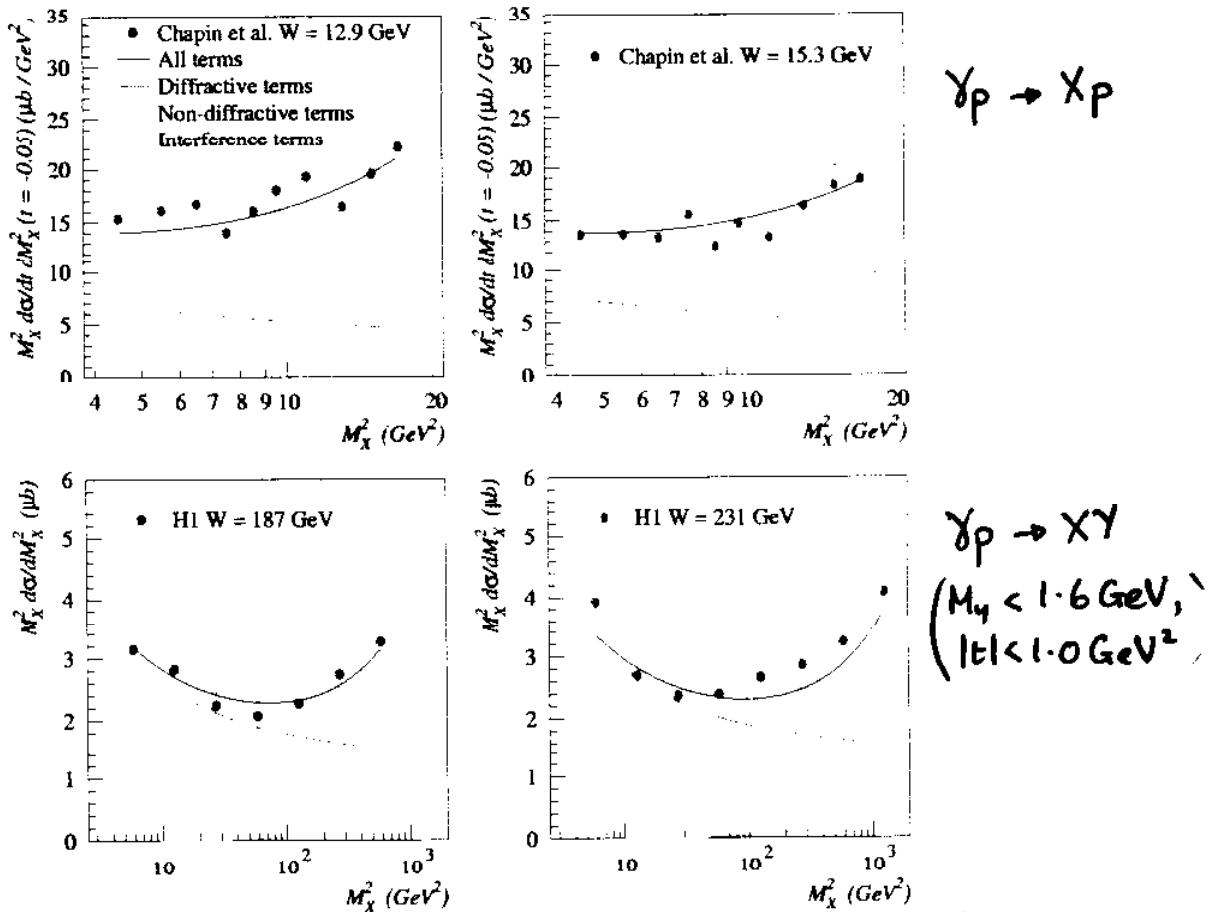
$$\sigma_{pp}^{(0)} = (116.3 \pm 11.0)^{\frac{1}{2}} \text{ stat.} \pm 1.8^{\frac{1}{2}} \text{ syst.} \pm 1.8^{\frac{1}{2}} \text{ syst.} \pm 0.0001 \text{ (from [1])}.$$

Both are dominated by diffraction.

Triple Regge Fit

- PPP, PPIR, IIRR, IRRR, IPRP, PRIR terms.
 - Maximal Constructive Interference.
 - No isospin-1 exchange.
- $\left. \begin{array}{c} \\ \\ \end{array} \right\}$ ROUGHLY EQUIVALENT
TO $R = f$

$$\chi^2/\text{n.d.f} = 19.9/30.$$



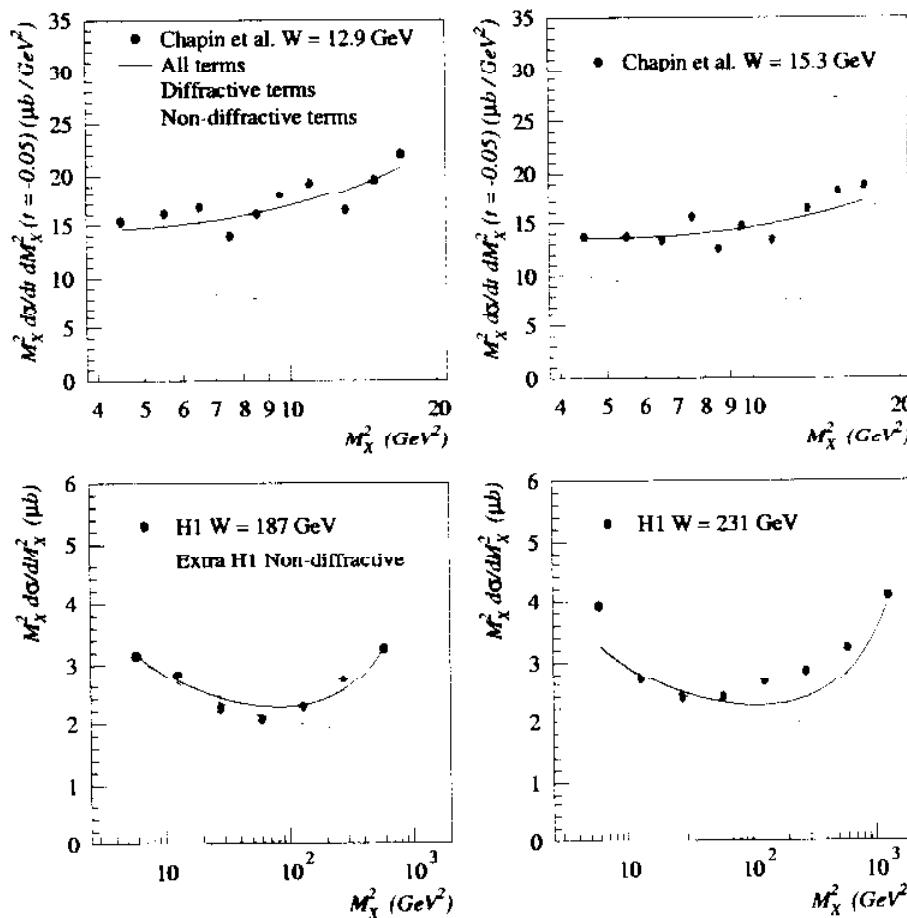
$\alpha_{\text{EM}}(t) = 1.101 \pm 0.001 + 0.001 \pm 0.022 + 0.001 \pm 0.001$
 Point out constant R at large W
 At low W , v dependent on sub-leading assumptions - factor of 2

Triple Regge Fit

- IPIP , IPPR , IRRP , IRR terms.
- No interference.
- $I = 1$ exchange, leading to extra states $Y^-(n, N^{*0}, \Delta, \dots)$ in H1 Data.

$\left. \begin{array}{l} \\ \end{array} \right\}$ ROUGHLY EQUIVALENT
TO $R = \rho$ OR a .

$$\chi^2/\text{n.d.f} = 18.4/29.$$



$$C_{\text{PIP}}(t) = 1.07 \pm 0.02 \quad C_{\text{IPR}}(t) = 1.07 \pm 0.02 \quad C_{\text{IRR}}(t) = 1.07 \pm 0.02$$

Further Results from the Fits

The three fits performed give a fair reflection of the theoretical uncertainties in the sub-leading contributions.

Averaging the results with the three different assumptions and including the variation in the model dependence uncertainty:

$$\sigma_{\gamma p}(0) = 1.068 \pm 0.016 \text{ (stat.)} \pm 0.022 \text{ (syst.)} \pm 0.011 \text{ (model.)}$$

Integrating the diffractive (IP exchange) contribution to $\gamma p \rightarrow Xp$ for $4 \text{ GeV}^2 < M_X^2 < 0.05 W^2$ at $\langle W \rangle = 187 \text{ GeV}$ yields:

$$\frac{\sigma^D}{\sigma_{\gamma p}} = 0.4 \pm 0.1 \text{ (stat.)} \pm 0.5 \text{ (syst.)} \pm 0.7 \text{ (model.)}$$

Including the resonance region, we obtain for

$$0 < M_X^2 < 0.05 W^2 \text{ at } \langle W \rangle = 187 \text{ GeV}$$

$$\sigma^D = 34.0 \pm 0.9 \text{ (stat.)} \pm 2.3 \text{ (syst.)} \pm 2.7 \text{ (model.)}$$

This represents a fraction of the total γp cross section

$$\frac{\sigma^D}{\sigma_{\gamma p}} = 22.2 \pm 0.6 \text{ (stat.)} \pm 1.6 \text{ (syst.)} \pm 1.7 \text{ (model.)}$$

The diffractive contribution at $\langle W \rangle = 14.3 \text{ GeV}$ varies by a factor > 2 depending on the assumptions regarding the sub-leading terms.

Conclusions

The cross section for $\gamma p \rightarrow XY$ behaves similarly to that for production of low mass states in hadron-hadron interactions.

- There is a pronounced "elastic" peak where $M_X \sim M_\rho$ and $M_Y \sim M_P$.
- At sufficiently large M_X , the cross section is approximately $\frac{d\sigma}{dM_X} \sim \frac{1}{M_X^2}$. The peak is shallower at larger M_X ($\sim M_P$).

Both the W and the M_X dependence of the cross section for $\gamma p \rightarrow Xp$ can be described in a triple Regge model.

- The dominant exchange at $W \sim 200$ GeV is the IP .
- At the largest M_X values considered, the other exchanges become important. The value of $\alpha_{\text{IP}}(0)$ is $\alpha_{\text{IP}}(0) \sim 0.75 \pm 0.05$, determined by all of f , ω , p or a .
- The value obtained for $\alpha_{\text{IP}}(0)$ is consistent with that describing total and elastic hadronic and photoproduction cross sections.
- Uncertainties in the sub-leading terms prohibit firm conclusions regarding the factor of 2 in $\alpha_{\text{IP}}(\text{low } W)$.

More data at intermediate W would set this out.

+ Leading neutron / proton measurement.

Triple Regge Fits

1. Pomeron only (PIPPIP)

$$\chi^2_{\text{redf. stat.}} = 81.9/33$$

2. Diffraction only (PIPPIP and PIPR)

$$\chi^2_{\text{redf. stat.}} = 74.1/32$$

3. No Interference (PIPPIP , PIPR IRIP and IRR) -

Roughly equivalent to $\text{IR} = \omega$

$$\chi^2_{\text{redf. stat.}} = 74.1/32$$

4. Maximal Constructive Interference (PIPPIP , PIPR IRIP , IRR PIR , IPR). Interference terms constrained by non-interference terms)

Roughly equivalent to $\text{IR} = i$

$$\chi^2_{\text{redf. stat.}} = 110.3/30$$

5. Isospin or Charge exchange in H1 data, so IR exchange terms are normalised differently from low energy data - (PIPPIP , PIPR IRIP , IRR)

Roughly equivalent to $I = 1$ $\text{IR} = \rho / \alpha$

$$\chi^2_{\text{redf. stat.}} = 18.7/21$$